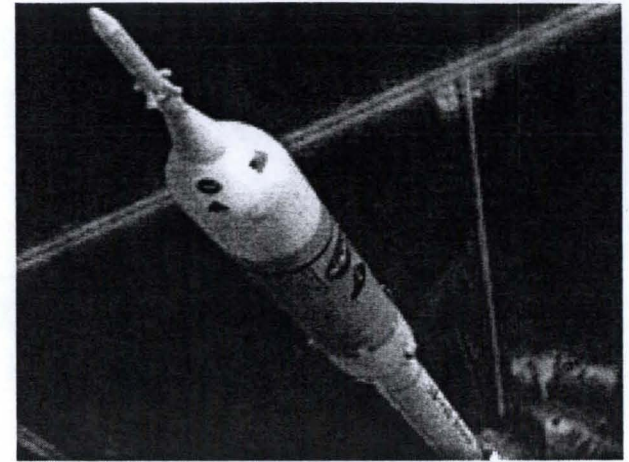
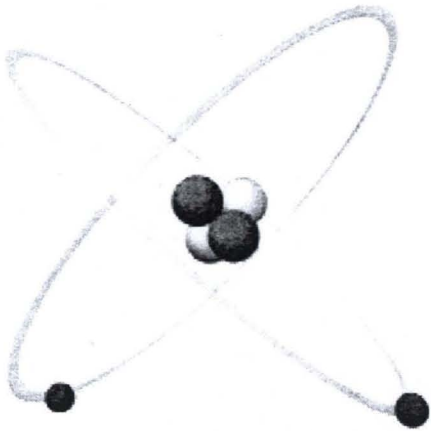


# Ares Integrated Vehicle System Safety Team

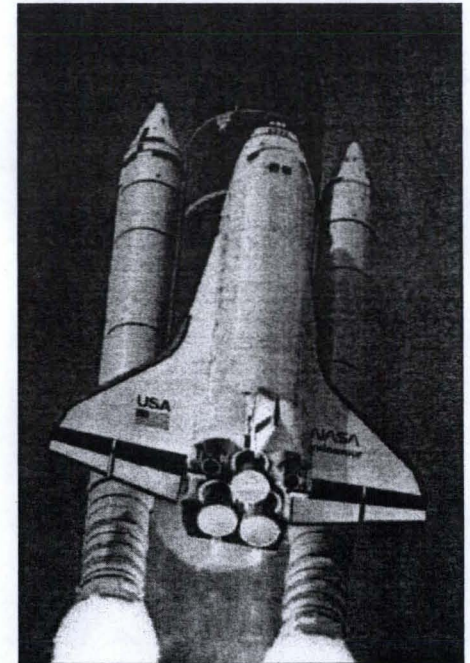
Jon Wetherholt

NASA Marshall Space Flight Center  
Launch Systems Integration Branch

April 16, 2008



Complex systems require integrated analysis teams.



Safety analysis is one of the most difficult aspects of integration

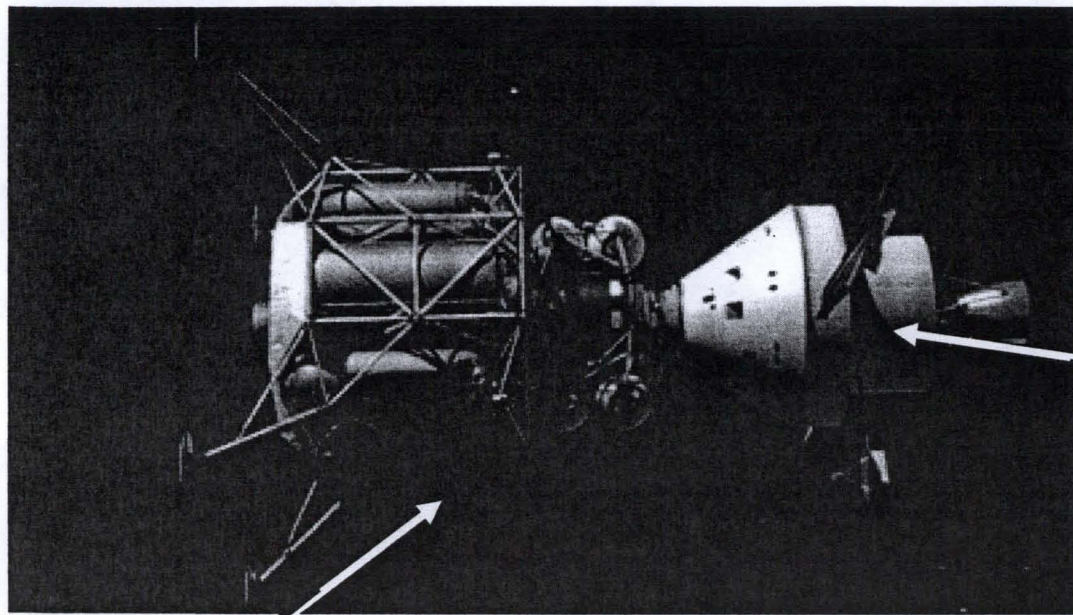
# An Example from History

“Over the last two decades, little to no progress has been made toward attaining integrated, independent, and detailed analysis of risk to the Space Shuttle system. System safety engineering and management is separated from mainstream engineering, is not vigorous enough to have an impact on system design, analysis hidden in other safety disciplines at NASA Headquarters.” Columbia Accident Investigation Report, Pg. 193, August 2003



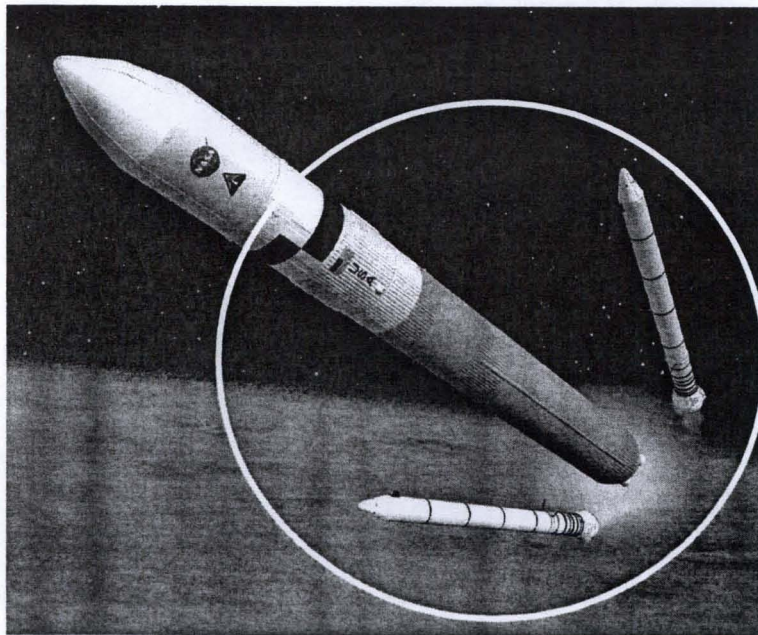
# A New Opportunity

- NASA is working on the Constellation Program to go to the Moon and beyond. The Program contains a number of projects:
  - The Ares I Launch Vehicle for the Orion Crew Module
  - The Ares V Launch Vehicle to launch large payloads into orbit, including the Earth Departure Stage (EDS)
  - The Orion vehicle to transport the crew to orbit and to other destinations
  - The Altair Lunar Lander



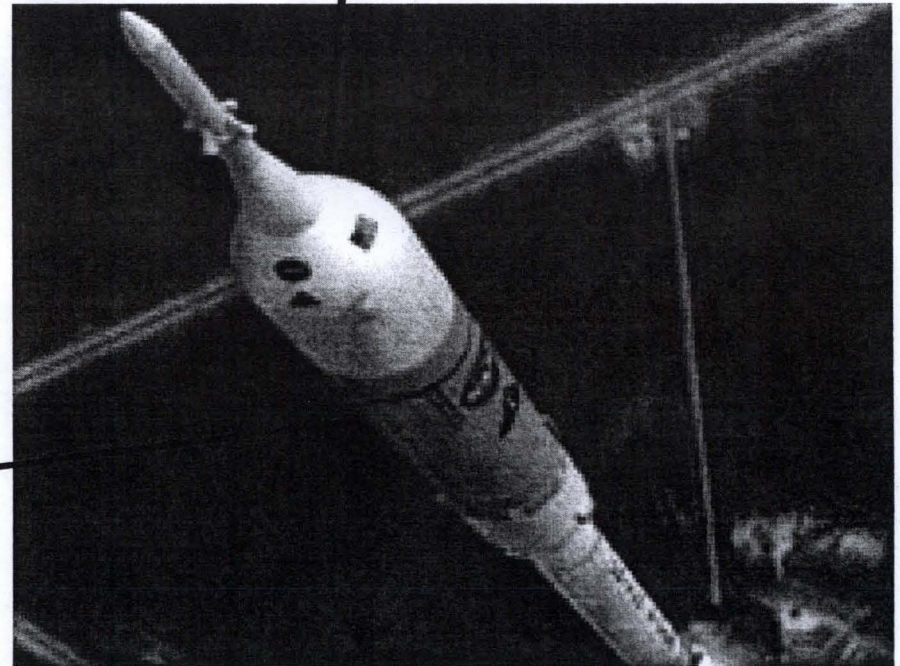
Orion

Altair



Ares V

Ares I



# A New Opportunity

- The Ares Project managed by NASA Marshall Space Flight Center contains
  - The First Stage, a solid rocket motor based on the Shuttle Solid Rocket Booster
  - The Upper Stage, with similarities to the Shuttle External Tank and other launch vehicles
  - The Upper Stage Engine, based on the J-2, liquid oxygen/liquid hydrogen upper stage engine for Saturn V



# Ares I Crew Launch Vehicle



- ♦ ~25-mT payload capacity
- ♦ 2-Mlb gross liftoff weight
- ♦ 309 ft in length

## First Stage

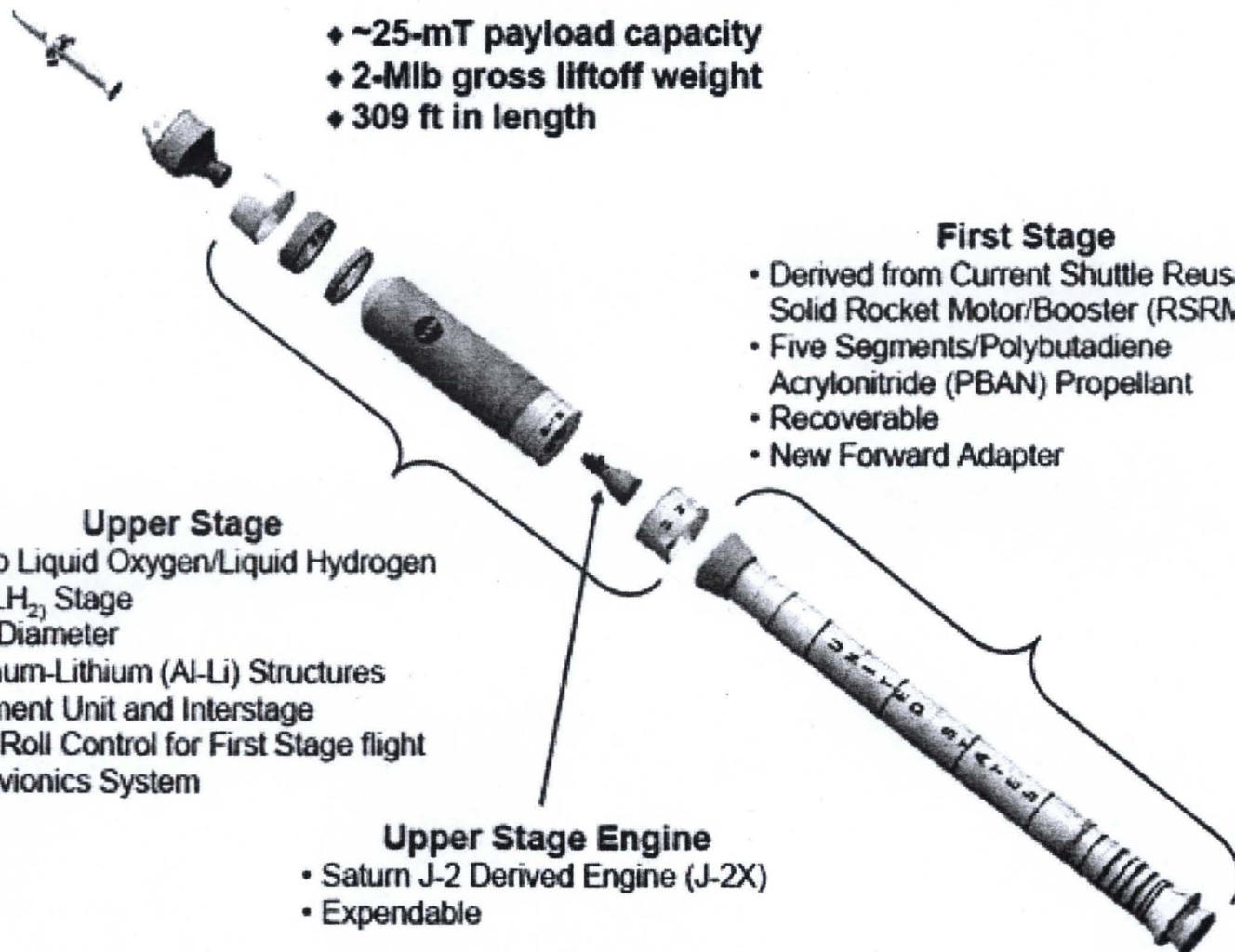
- Derived from Current Shuttle Reusable Solid Rocket Motor/Booster (RSRMB)
- Five Segments/Polybutadiene Acrylonitrile (PBAN) Propellant
- Recoverable
- New Forward Adapter

## Upper Stage

- 280-klb Liquid Oxygen/Liquid Hydrogen (LOX/LH<sub>2</sub>) Stage
- 5.5-m Diameter
- Aluminum-Lithium (Al-Li) Structures
- Instrument Unit and Interstage
- RCS / Roll Control for First Stage flight
- CLV Avionics System

## Upper Stage Engine

- Saturn J-2 Derived Engine (J-2X)
- Expendable



# Ares Project Elements

- The Project is divided by Element
  - First Stage has a contractor for the element, management is in-house at MSFC (existing working relationship from Shuttle)
  - Upper Stage Engine has a contractor for the element , management is in-house at MSFC (existing working relationship from Shuttle)
  - Upper Stage is in-house for design
  - The Vehicle Integration portion of the project is in-house



# Ares System Safety

- Formation of Safety Teams for the Project
  - Each element has a safety team
    - First Stage has a contractor to develop the hazard analysis and hazard reports
    - Upper Stage Engine has a contractor to develop the hazard analysis and hazard reports
    - Upper Stage performs the hazard analysis and develops the hazard reports in house
    - The Vehicle Integration portion of the project performs the hazard analysis and develops the hazard reports in house

# Ares Vehicle Integration (VI) System Safety

- Interrelated Vehicle Integration Safety Issues
  - Lack of available trained system safety engineers
    - Other projects nation-wide have created a demand
    - System Safety is rarely available in college and university curricula
  - Difficulty breaking down a complex system into a complete understandable number of hazard reports
  - Communicating of the integrated hazards to engineering, project and program management

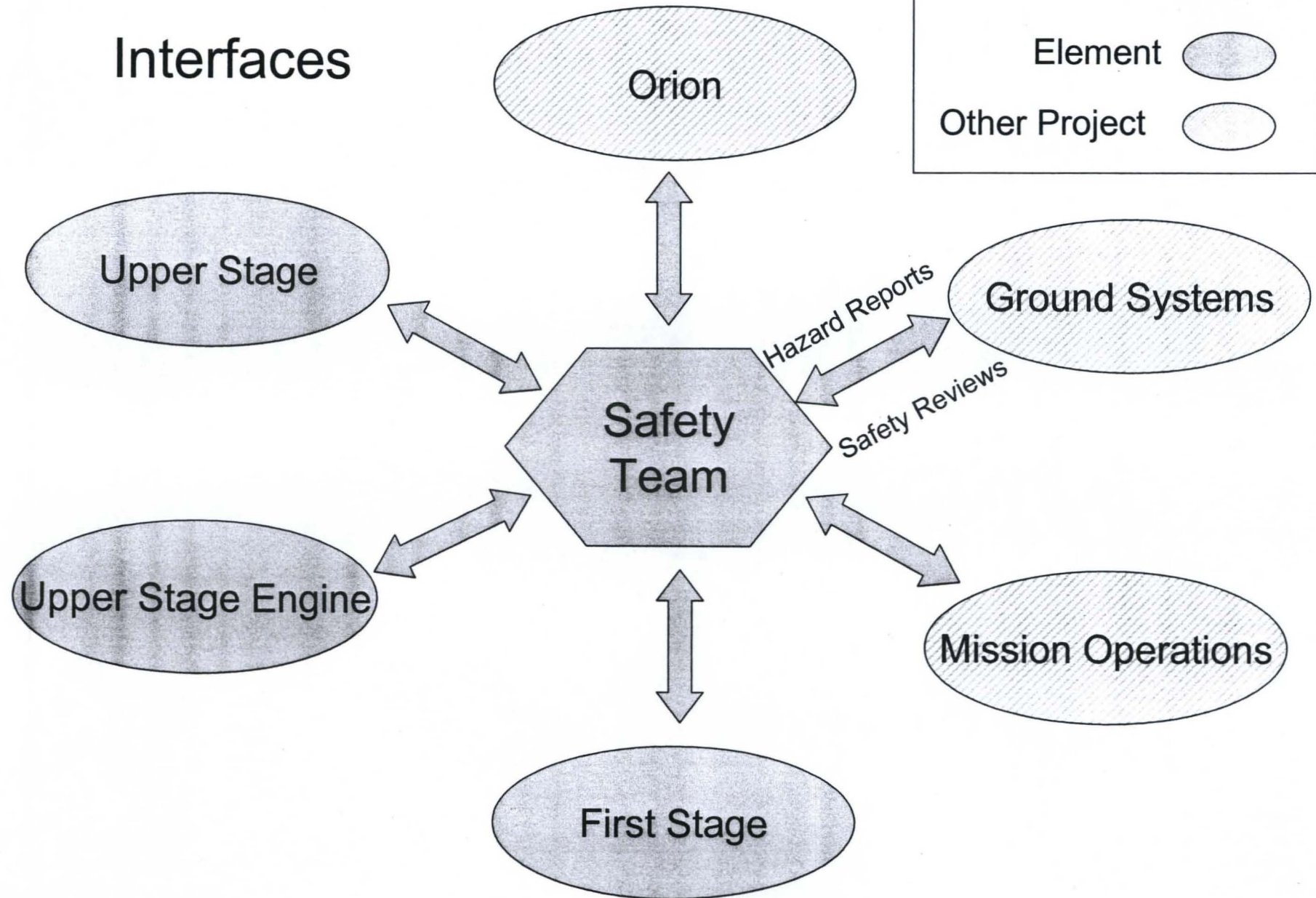
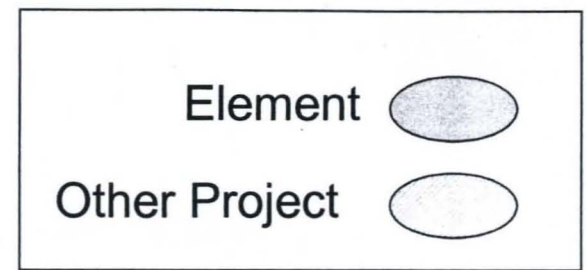
# Ares VI System Safety

- The Team

- Formed a team with a combination of experience in
  - Integrated hazard analysis for space systems
  - Systems engineering
  - Integrated hazard analysis for other types of complex government systems (e.g., other Constellation projects, military projects)
  - Specific NASA disciplines related to safety (e.g., Range Safety, reliability)
- Formed a team which would interact in an open forum



# Interfaces



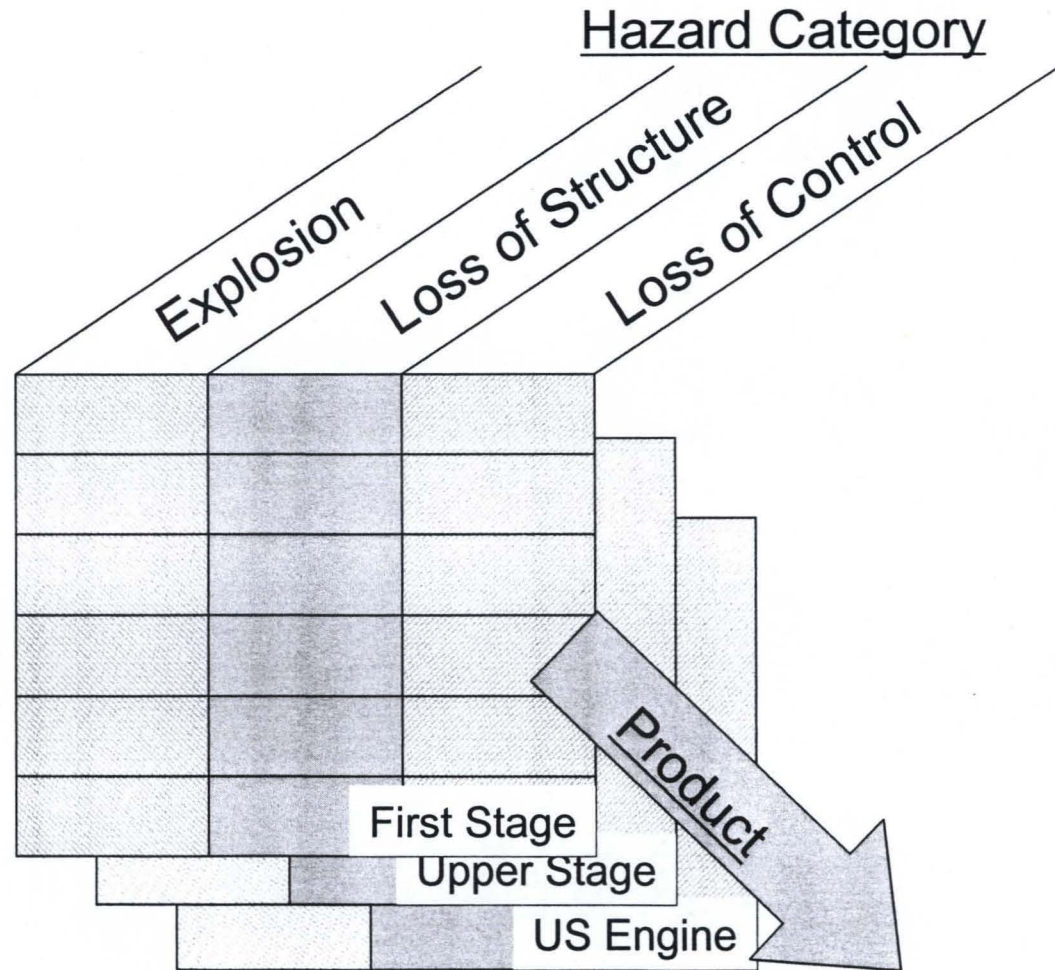
# Ares VI System Safety

- Team break down choices
  - By Discipline (e.g., electrical, mechanical, fluids, software)
    - Advantage: Keeps engineers in their comfort zone
    - Disadvantage: One person of each discipline is not available
  - By Product (Elements)
    - Advantage: Easy to follow element hazard reports
    - Disadvantage: Makes integration across elements difficult
  - By Hazard Category (using customized standard hazard list)
    - Advantage: Integrates across elements with one person being responsible for a category
    - Disadvantage: Requires interface with multiple elements

Which  
Way to  
Divide?

Discipline

Electrical  
Mechanical  
Software  
Fluids  
Structural  
Operations





# Ares VI System Safety

- Ares Integration uses Hazard Category breakdown because
  - The Ares elements use hazard category
  - Past accidents integrated hazards cut across disciplines and have been related to a hazard category
    - Challenger was fire explosion caused by leakage
    - Columbia was structural failure caused by debris

# Ares VI System Safety

- Communication

- With element engineers (Upper Stage, Upper Stage Engine, First Stage)
  - The element system safety engineers are part of VI team meetings
  - The element project engineers review the hazard reports
  - Ares VI attends element safety reviews
- With Engineering Directorate
  - An Engineering representative is on the Ares VI safety team
  - A process is in place for Engineering to review hazard reports and analysis
  - There is interaction through support of milestone reviews, meetings, and trade studies
- With Ares Project Management
  - A Management process is in place to review Hazard Reports and Analysis to approve them

# Ares VI System Safety

- Communication (continued)
  - With the Program
    - Presentation of the Hazard Analysis and Hazard Reports through a safety engineering review panel
      - Constellation Safety Engineering Review Panel (CSERP)
        - » Panel chaired by Program Safety
        - » Panel supported by System Safety experts
        - » Panel supported by Project and Program engineering
      - CSERP reviews safety products
        - » Products provided in written format
        - » Products are presented at panel meetings
      - CSERP reports to Program Manager
        - » Provides input on risk acceptance
        - » Brings forth hazards for acceptance by other cognizant panels



# Conclusion

- System Safety Team formation must
  - Consider outside constraints (e.g., availability of staff)
  - Consider how interfacing teams are arranged
  - Consider the most effective way to assign areas for analysis to integrate across systems